

Qualification of Solutions for Improving Fatigue Life at SCR Touch Down Zone

Rajiv K. Aggarwal, Granherne Inc., Houston, TX, USA

Shankar U. Bhat, Granherne Inc., Houston, TX, USA

Trond S. Meling, Statoil ASA, Stavanger, Norway

Marcio M. Mourelle, Petrobras, Rio De Janeiro, Brazil

Cornelis van der Linden, TOTAL E&P USA, Inc., Houston, TX, USA

Michael Else, Minerals Management Service (MMS), Herndon, VA, USA

ABSTRACT

Steel Catenary Riser (SCR) is a proven and economic riser system solution, as a tie-back production riser and as an export riser from floating production systems, in development of oil and gas fields in deepwater and ultra-deepwater. But application of SCRs is challenged in some cases due to high fatigue damage at Touch Down Zone (TDZ) from a combination of field specific parameters, such as riser size, fluid characteristics, vessel motions, metocean parameters, soil conditions, and water depth. A number of solutions to this problem were considered in a JIP during 2004 and four selected solutions were carried forward to qualification testing and analysis during 2005. An overview of the current status of the JIP is provided. The JIP is being supported by 10 companies, including 5 major manufacturers whose products are used in these solutions. The solutions for fatigue life enhancement at SCR TDZ include use of: titanium segment; light weight coating over steel riser sections; high strength steel riser sections with integral connectors; and steel riser sections with upset ends. The different mechanisms through which fatigue life enhancement is achieved for these four solutions are discussed. The analyses performed for two case studies, which included production riser with sour service and HPHT fluid, and large diameter export riser, estimated potential increase in fatigue life by a factor of 3 to more than 100 from these solutions. The qualification testing program undertaken for each solution and their benefits are outlined. The primary objective of qualification testing effort is to increase project readiness of these solutions for consideration of SCR with TDZ enhancement at the concept selection and front end engineering stages of deepwater field development projects. Such enhancements would also be valuable to the SCR Integrity Management program, by influencing decision on inspection cycles and frequency, and benefiting life-cycle cost.

INTRODUCTION

The application of steel catenary riser (SCR) design for production and export of hydrocarbons from floating production and storage units has increased during past decade. The production SCRs are used for tie-up of subsea wells to a floating facility, and export risers are used for transport of oil and gas to loading terminals or shore based facilities. The combined effect of various parameters, such as fluid type and properties, riser diameter, water depth, vessel type and motions, in some cases leads to estimates of significantly high fatigue damage at touch down zone (TDZ) of SCR design and thus make it technically unfeasible riser design for certain deepwater floating production system projects.

Various possible solutions for improvement of fatigue life at SCR TDZ were identified previously through studies [1, 2] and project applications [3]. Some of these were proposed in deepwater projects, but were not considered further due to lack of detailed information on product availability, design, manufacturing, installability, and pre-qualification data. These solutions are also expected to find applications in ongoing projects with change in design criteria or field specific data at a later stage of project or upon placement of material order, as a remedial measure to enhance fatigue life at SCR TDZ. Through the SCR Touch Down Zone fatigue JIP (SCR JIP), an attempt is being made to advance selected solutions for enhancement of SCR TDZ with high near-term application potential, through design development and qualification testing to bring them to project ready stage.

The following alternatives are known to have been considered so far by some operators to increase fatigue life at SCR TDZ:

- Better fit-up at welds through machining ID and improved welding techniques
- Movement of floating vessel periodically to distribute fatigue damage over longer length at the SCR TDZ
- Steel riser sections with thick forged ends welded onshore to ensure very good fit-up and reduce SCF at offshore welds between forged ends. This has also been used for near surface flowlines.
- Clad steel to reduce effects of degradation of S-N curve in sour service

The increase in fatigue life through first three of these measures is estimated to be within a factor of 2 to 3. The improvement is higher for clad steel option, which is applicable in specific cases involving corrosive fluids or sour service. The objective of SCR JIP is to develop additional TDZ solutions with potential to provide fatigue life enhancements by factor of 10 or more.

Additional variations in catenary shaped riser designs that have been studied to improve strength and fatigue for feasible catenary riser designs are identified as follows:

1. Lazy wave steel catenary riser with significant buoyancy in a region near the seabed [4, 5, 6]
2. Titanium catenary riser (TCR) [7]
3. Weighted riser – Titanium in most part (TCR) or hybrid titanium and steel [8]
4. Composite catenary riser (CCR) [9]

These solutions aim at making the catenary riser feasible for specific applications, water depths, and regions primarily from strength considerations. In all of these cases, the fatigue life at TDZ improves due to use of different material or through change in the riser configuration. The lazy wave catenary riser has been evaluated for SCR applications with deepwater FPSOs and FSOs, whereas solutions 2 to 4 have been evaluated for the North Sea (NS) conditions. The overall cost associated with these alternative catenary riser designs is significantly high. None of these solutions have been used in a project so far.

The most common riser design used in the past with deepwater FPSOs is the riser tower, as in Girassol project in West of Africa (WOA). The SCR design was recently used or is being considered with tanker based FPSOs in WOA and offshore Brazil. In WOA region both wave and fatigue environment are less severe compared to Gulf of Mexico (GOM) and the North Sea. In offshore Brazil the maximum wave heights are smaller, but wave fatigue environment is critical. However, special design considerations were required at TDZ. SCRs are also being considered in recent semi-submersible projects.

Thus there is a need to develop and qualify solutions to enhance conventional SCR TDZ design for achieving significant increase in fatigue life. The solutions being further developed and qualified through this JIP aim at potential applications to SCR designs with adequate strength but with significantly high fatigue damage at TDZ. The solutions selected for detailed work in this JIP have potential for fatigue life improvement by a factor of 10 or more and with higher potential for near-term application. In general the application of solutions undertaken in this JIP require enhancement of a short length at TDZ to increase fatigue life. When application of some of these solutions is extended to improve riser strength in addition to fatigue at/near TDZ, then the length requiring enhancement will become significantly longer, since the

strength aspects will need to cover both “far” and “near” configurations of SCR. However, the qualification work undertaken within this JIP is also applicable to such requirements.

JIP WORK PLAN

The JIP work plan includes various tasks from selection of solutions to their analysis, design development, and qualification under the following four stages:

- Stage I: Comparative assessment of alternative SCR TDZ solutions
- Stage II: Case study analyses
- Stage III: Design development and qualification assessment
- Stage IV: Qualification testing and analysis

In Stage I, comparative assessment task, a total of 15 alternatives and additional combinations were evaluated and specific information was obtained from single or multiple suppliers for each solution. These solutions fall under the following three categories:

- Components to fit solutions
- Material change at SCR TDZ
- Add-ons to conventional carbon steel riser sections at TDZ

Threaded & coupled connectors, welded on threaded connectors, flanges, thick forged ends welded onshore, and upset pipe were considered under the first category above. Besides steel, titanium, composite, flexible pipe, aluminum alloy, clad steel, duplex and super duplex steel were considered under the second category, for riser sections at TDZ and connected to conventional SCR above and below TDZ by use of specific connectors solutions identified or by welding. The add-on solutions included light weight coating, buoyancy modules, clamps or sleeves, and these were considered over steel riser sections only. In addition, low lazy wave riser was included in assessment as an alternate riser configuration.

The selection criteria included various factors such as technical feasibility, application limits, potential improvement in fatigue life, overall cost and schedule, design maturity and history of application, complexity of solution, qualification status, near term applicability, and number of suppliers. Weighting factors were allocated to the criteria and a ranking was developed, which was then reviewed with the JIP participants.

The selected SCR TDZ enhancement solutions with high value and increased likelihood for near term application were then taken up with specific product manufacturers for further work in the JIP:

- Titanium segment with RTI Energy Systems, Houston, USA
- Light weight coating over conventional steel riser sections with SocoRIL, Escobar, Argentina
- Steel riser sections with integral connectors with VAM PTS, Houston, USA, and V&M Tubes, Aulnoye-Aymeries, France
- Steel riser sections with upset ends with V&M Deutschland, Dusseldorf, Germany
- Steel riser sections with upset ends with Tenaris Tamsa, Veracruz, Mexico

The case study analyses in Stage II were done for two regions to help establish practical application and design requirements for SCR TDZ enhancement for each solution. The studies were done for GOM and WOA for production and export risers supported by a semi-submersible or a tanker based FPSO respectively. The applications at TDZ are expected to be similar in several other regions, and in some regions as North Sea the enhancement would be required over longer length at TDZ.

The requirements established from the case studies formed the basis for design development, assembly and connection requirements, installability assessment, schedule and cost estimates, qualification assessment, and qualification analysis and testing work in Stages III and IV for each solution.

Several approaches for qualification have been proposed by class societies and other companies, which have been used for pre-qualification of new applications and technologies. These approaches were considered in this JIP and adapted as were feasible for this application and based on available information. The approach used varies with each solution, but in general included the following:

- Identify and develop system level design and address manufacturing, construction, installability, schedule, and cost issues
- Identify and obtain detailed information on additional components, such as connection and select an alternative for application at TDZ
- Overall review of application of a solution at TDZ to identify critical failure modes
- Identify and compile available information on the main product and additional sub-components, and experience from previous applications and qualification work
- Develop a qualification analysis and testing program to address specific issues of importance to application at TDZ
- Undertake detailed finite element analysis (FEA), where necessary
- Undertake testing program with participating product manufacturers, suppliers, and major laboratories
- Perform evaluation of test and analysis results and identify qualification status established and the issues requiring further work by industry

The key objective of the JIP through the above tasks is to improve project readiness of four SCR TDZ solutions, thus enabling their consideration at the front end engineering stage of site-specific field development projects in deepwater and ultra-deepwater fields. Potential benefits of this JIP study include the following:

- Establish readiness of selected solutions for near-term application through implementation of technology qualification process
- Improve field development economics through increasing range of application of SCR design for deepwater FPS units
- Enable application of SCR design for HP-HT and sour service cases
- Assess comparative value of various TDZ solutions

CASE STUDIES

Two case studies were undertaken in the JIP to identify TDZ enhancement requirements and estimate increase in fatigue life from each solution. The GOM case studies considered SCRs on a semi-submersible vessel in 4,000 ft (1,220 m) water depth, whereas the WOA case study considered SCRs on a FPSO in 2,460 ft (750 m) water depth. In the case of GOM production riser the fluid properties considered were for high pressure, high temperature, and sour service case to evaluate worst case scenario.

The following four different modes (or their combinations) of SCR design and riser system behavior, are utilized to enhance fatigue life through application of selected solutions discussed in this paper:

- *Material change:* Use of high-strength, non-corrosive material, such as Titanium and C110 steel

- *Increase buoyancy to reduce soil-structure interaction:* Lightening of SCR TDZ to achieve reduction in riser bending stresses and increase in fatigue life
- *Replace welds by mechanical connections:* Eliminating welds at SCR TDZ through use of integral connectors
- *Increase riser pipe wall thickness at offshore and onshore welds:* Thickening of the riser pipe wall thickness at welds to reduce stresses and obtain increased fatigue life

Strength, fatigue, and VIV analyses were done in case studies for TDZ enhancement solutions that could be supplied by product manufacturers for riser diameter and thickness considered. Time domain irregular wave analysis was performed using Riflex, and included both wave frequency (WF) and low frequency (LF) vessel motions. Fatigue damage was estimated using Rainflow Counting method. Simplified VIV analysis using a single critical current was done to estimate VIV response.

The base case analyses for case studies showed that only part of the SCR TDZ length will have high fatigue damage, and requires measures to improve fatigue life. Thus for this JIP work a length of 100 m (320 ft) was considered for titanium, integral connector, and upset end solutions, and a length of 300 m (1,000 ft) was considered for light weight coating case.

The fatigue life improvement factors estimated for two case studies are summarized in Table 1. The targeted fatigue life improvement factors were estimated as 8 times for production riser and 3 times for export riser for GOM case study, whereas targeted factor for WOA case study production riser was only 3. In case of titanium and integral connector solutions, which were estimated for GOM case only, the available increase in fatigue life was significantly higher due to change in material and in case of production risers due to selecting grades with higher resistance to sour service fluids.

TITANIUM SEGMENT SOLUTION

Titanium segment solution has potential to provide very high increase in fatigue life due to its high strength, low modulus, better S-N curves compared to steel, and excellent chemical resistance. The titanium riser sections at TDZ are required of Grade 23 for non-sour service and of Grade 29 for sour-service applications.

The case study for GOM estimated about 100 m (320 ft) length at SCR TDZ to require enhancement by replacing steel riser sections with titanium segment. The case studies identified that for certain applications use of heavy weight coating over titanium segment may be desired, to compensate for reduced weight of titanium sections and eliminate upheaval during empty condition, which may occur infrequently during the life of the riser.

The overall system design of titanium segment at TDZ, manufacturing methods, and feasible sizes were reviewed, and installability assessment was done to establish feasible options. An evaluation of the overall system for different phases of a project was done to identify critical failure modes and specific issues to focus in the JIP. The available qualification status of key components and operations were identified and the companies responsible were contacted to obtain details for evaluation.

The important areas requiring detailed assessment in the JIP were identified as follows:

- Connection of titanium-to-titanium and titanium-to-steel riser sections
- Isolation system need and requirements between steel and titanium riser sections
- Required surface finish for good adhesion to coating, to prevent premature crack initiation, and to detect flaws by ultrasonic testing (UT)
- Heavy weight coating alternatives

Extensive qualification testing has been undertaken by several companies and manufacturers in Norway and by RTI Energy Systems for titanium pipe, welding, corrosion, fatigue, different surface finish and their effects on S-N curves. Under DEMO 2000 program in Norway, significant qualification work for material,

corrosion, welding, rubber coating (with Trelleberg Viking) was undertaken [7, 8], and DNV has also carried out additional qualification testing in connection with the preparation of their recommended practice for titanium risers [10]. Procedures for welding titanium offshore on an installation vessel have not been qualified, and the connections offshore are to be made using mechanical connectors as done for a titanium stress joint (TSJ).

The details of SPO compact flange [11] and previous qualification test and reliability reports were obtained from Vector International and reviewed for SCR TDZ specific issues. Such flanges have been used in the past to connect riser sections with TSJ, which are subjected to fatigue, internal pressure, and high tension loads. An illustration of SPO compact flange is given in Figure 1. The important design consideration of SPO compact flange is to achieve preloading of bolts and three-part sealing system as follows:

- Inner metal-to-metal seal at the flange heel adjacent to the bore, to ensure no gap between the flanges at the bore during operations and to protect the primary seal.
- Flexible metal ring located in a seal ring groove as the primary seal, which is pressure energized by the deformations of seal flanges towards seal centerline and also when subjected to pressure either from inside or outside.
- Outer metal-to-metal seal at the outer wedge after make-up prevents ingress of materials to flange faces and bolting cavity.

The preloading of bolts and flange face to face contact after makeup enables eliminate the risk of load induced seal damage. The integrity of the primary seal can be determined by the use of a test port to the primary seal groove, which can be pressure tested. Significant finite element analysis have been done by both Vector International and RTIES for designs applied in various riser TSJ's to confirm strength and fatigue integrity of this mechanical connection.

There is need to develop a new design of an isolation system between steel and titanium riser sections for hot sour flows with high water cut for dynamic applications, such as at SCR TDZ. However for most applications the currently available designs are found adequate.

In case of TDZ enhancement of a production SCR, the heavy weight coating is required only over the titanium segment and the rest of SCR will have normal insulation coating. The heavy weight coating solution, Vikoweight, by Trelleberg Viking has been qualified for bondability on titanium in DEMO 2000 project [5,6].

The feasibility of an alternative syntactic polypropylene coating system over titanium as insulation and for heavy weight coating proposed by SocoRIL is being evaluated in this JIP. The key issue identified for this case is the ability to achieve desired anchor profile and bond strength of surface finish with Wheelabrator grit blasting. The qualification testing work undertaken in this JIP includes the following:

- Titanium segment surface preparation and coating integrity testing
- Laboratory metallurgical examination and seawater corrosion testing of grit blasted titanium samples
- S-N fatigue tests on grit blasted Gr. 29 titanium pipe strip specimens to assess suitability for riser service

LIGHT WEIGHT COATING SOLUTION

This solution comprises of lightening of TDZ to increase the fatigue life through reduction in stresses at welded connections. In this case, the fatigue S-N curves remains same for a weld type and details as a conventional SCR design. The execution plan remains similar to the SCR with insulation coating, except that due to providing very thick light weight coating the feasible approach will be J-lay installation. In addition some vessels are available with both reeling and J-lay tower, and their feasibility to install SCR TDZ with thick light weight coating could also be considered.

The case studies and additional evaluations estimated that the length of application of light weight coating over steel riser sections for SCR TDZ enhancement could range from 1,000 ft to 1,200 ft and require up to 13 inch thick coating over production or export risers. The overall density of light weight coating is 660 kg/m³ compared to normal insulation density of 790 kg/m³.

The light weight coating characteristics and design is similar to the proven five layer syntactic polypropylene, which is qualified by SocoRIL and used in several recent projects. At present, the 5-layer syntactic PP has been qualified for 5 inch thick insulation coating. The five layers of this coating system shown in Figure 2 are as follows:

- Fiber bonded epoxy
- PP adhesive
- Solid polypropylene
- Syntactic polypropylene
- Solid polypropylene

The first three layers in this design are for anti-corrosion. The design of fourth layer is varied to obtain light weight density through introduction of glass hemispheres. The function of the fifth layer is to provide protection and ensure integrity, and by varying its thickness the wear and abrasion requirements are met.

The qualification testing plan for this case was developed based on evaluation of design, construction, installation issues and identification of critical failure modes. The following tests are being undertaken to confirm application feasibility, integrity of coating in strength and fatigue:

- Application of 10" thick syntactic PP coating on 10.75" diameter riser pipe
- Series of lab tests for properties and integrity of LWC to be undertaken before and after the full scale tests
- Full scale bending and fatigue tests of steel pipe samples with very thick coating
- Application of field joint coating using solid polyurethane
- Installation bending and impact test

INTEGRAL CONNECTOR SOLUTION

Integral connector solution provides higher fatigue life through elimination of welded joints at SCR TDZ, use of higher grade steel, and manufacturing of upset ends integral with the riser section, which is generally 40 ft in length.

The integral connector design from VAM PTS (V&M Tubes) considered in this JIP for application at SCR TDZ is manufactured using high grade steel P110 and has smaller OD compared to weld on connectors. In case of sour service application, use of C110 steel is being considered. The connector is manufacturable for up to 13-5/8" diameter production risers. The solution comprises of the following key sub-components or properties/mechanisms that ensure integrity of the system and higher estimated fatigue life:

- Internal and external shoulder to withstand high bending
- Optimized make-up torque to preload connector to provide high fatigue resistance
- Internal and external metal/metal (M/M) seal to provide highest pressure integrity
- Improved thread profile for high fatigue performance

In the JIP, system design at TDZ with connectors and cross-over segments from X-65 to P-110 PDW-1 connector segments and the critical failure modes were identified, and the design considerations for these

failure modes were discussed with VAM PTS. The installability of TDZ segments and feasibility of making such connections from J-lay tower were reviewed in detail with major installation contractors and connection tool suppliers, and feasible approaches were identified.

The industry experience for threaded and coupled (T&C) connectors is mostly through top tensioned risers and tendons used in floating platforms. There are only a few applications of integral connectors similar to PDW-1 design, as in Heidrun TLP in the North Sea. Such connectors have been used previously for production casings supplied by major connector manufacturers. Therefore, qualification effort is necessary for SCR TDZ applications and through this JIP it is being done.

VAM PTS has an ongoing in-house program for development of such connectors with focus on manufacturing route qualification, sealability tests, and full scale fatigue tests.

The qualification program undertaken with VAM PTS for this JIP comprises of the following tasks:

- Participation in VAM PTS on-going qualification testing program through review of documents and test reports, and ongoing qualification testing
- Thorough evaluation of the overall system
- Develop cross-over segment from PDW-1 connector to X-65 welded riser section and perform conceptual evaluation. Evaluate alternative designs and perform FEA for cross-over segment with thick connector threads for selected design.

UPSET END SOLUTION

This solution provides higher fatigue life primarily through reduction in stresses at the upset end designed with increased wall thickness. The potential for increase in fatigue life is higher due to manufacturing of X65 steel grade riser sections with integral upset ends and ensuring weldability at upset ends through appropriate selection of metallurgical properties and measures taken during the upsetting process.

The length of riser sections with upset ends required at SCR TDZ is estimated to be about 100 m (320 ft), which is similar to that for titanium segment and integral connector solutions.

The following are important in the design development of upset end and transition zone:

- Upset length
- Taper transition length
- Inner diameter (ID) machining length
- Radii of curvature from taper transition to upset end and original pipe
- Machining of upset end, taper transition, and ID
- Feasibility to attach automatic welding and UT equipment

Finite element analysis (FEA) was performed to optimize transition zone design. The SCF at transition was kept below 1.2. This solution provides significantly improved fit-up at welds, which is reduced to the tooling tolerance. Thus, the SCF at welds and fatigue life are significantly improved.

The design development included establishing requirements for automatic welding and UT operations through discussion with major contractors. The feasibility of upsetting is limited to 16 inch diameter pipe by two manufacturers participating in this JIP. The maximum wall thickness could be increased up to 50% through upsetting depending on diameter and thickness of the original pipe.

Upsetting process has been proven through the work done for casing and riser connectors. The applications in these cases have mostly been for less thick pipes and higher grade for threaded connections. Figure 3 shows two stages in the upset end manufacturing process. The thicker upset ends for X-65 or equivalent grades used are forged ends welded onshore at ends of riser or flowline sections.

Therefore, there is a need to do qualification of integral upset end solution with good weldability offshore for larger diameter and thickness pipes used in production and export SCRs.

The qualification tests undertaken in the JIP focus on the following:

- Preparing samples with thicker and weldable upset ends
- Performing CNC machining
- UT testing
- Mechanical properties and laboratory material tests
- NACE corrosion tests – HIC and SSC
- Weldability tests – CTOD tests
- Full scale testing to confirm fatigue behavior of upset transition zone

The weldability tests are being performed per API RP 22 to establish toughness of the HAZ. The properties of HAZ depend on heat input during welding and the base material chemical composition. These tests include CTOD testing of HAZ, with welds produced with low (0.6 to 0.8 kJ/mm) and high (2.5 to 3.0 kJ/mm) heat input. The toughness values are to be measured at both fusion line and in the visible HAZ boundary material. The full scale fatigue test aims at conforming fatigue behavior at the upset transition zone.

The weldable upset end solution is being developed in the SCR JIP with both V&M Deutschland and Tenaris Tamsa.

CONCLUSIONS

The work presented in this paper confirms technical and economic feasibility of four new solutions for enhancement of SCR touch down zone with potential to provide significant improvement in fatigue life estimates. The JIP work has shown that the four selected solutions for enhancement of TDZ design provide different levels of improvements in the estimated fatigue life at SCR TDZ for an application. In some cases only a few of these solutions will be feasible to obtain desired increase in fatigue life, e.g., sour service application or large diameter export risers, due to manufacturing limitations, material properties. The relative value and cost of these solutions for an application will vary based upon characteristics of field and floating system as discussed in this paper.

Based upon work done so far in the JIP, the following interpretations can be made on potential use of these solutions:

Production riser:

- *Non-sour service case*
 - Titanium Grade 23 segment
 - Lightweight coating
 - Integral connector with P110 steel
 - Upset end solution
- *Sour service case*
 - Titanium Grade 29 segment
 - Lightweight coating with reduction in steel S-N curve
 - Integral connector with C110 steel
 - Upset end solution with reduction in steel S-N curve

Export riser:

- *Smaller Diameter (up to 14" OD or 16" OD)*
 - Titanium Grade 23 segment
 - Lightweight coating
 - Integral connector with P110 steel (up to 14" OD)
 - Upset end solution
- *Larger Diameter*
 - Lightweight coating
 - Titanium Grade 23 segment

The qualification work undertaken within this JIP is broad covering design, manufacturing, construction, transportation, installation, and in-service performance issues and it has resulted in providing clarity to their applications at TDZ. With significant development effort undertaken in this JIP, progress has been made to bring these solutions to project ready state and they can now be considered at front end engineering stage and beyond in SCR design development for site-specific applications worldwide.

The availability of these solutions also provide operators alternative remedial measures to consider in ongoing projects where significant changes in design criteria impact feasibility of the original floating system design and requires enhancement of SCR design. This may be more critical for cases where material orders are placed and design updates are found necessary. These solutions could also be valuable to SCR integrity management programs.

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Table 1: Estimated Fatigue Life Improvement Factors from Case Studies

SCR TDZ Solution	Gulf of Mexico		West of Africa
	10.75" OD Production Riser	24" OD Export Riser	10.75" OD Production Riser
Titanium Segment	426	183	Not done
Light Weight Coating	13 with 9" thick coating	3 with 5" thick coating	3 with 5" thick coating
PDW-1 Integral Connector	42	Not Applicable	Not done
Upset End Pipe	8.4 with 39% WT increase	3 with 29% WT thickness increase	3 with 20% WT increase



Figure 1: SPO Compact Flange
[Source: Vector International, Norway]

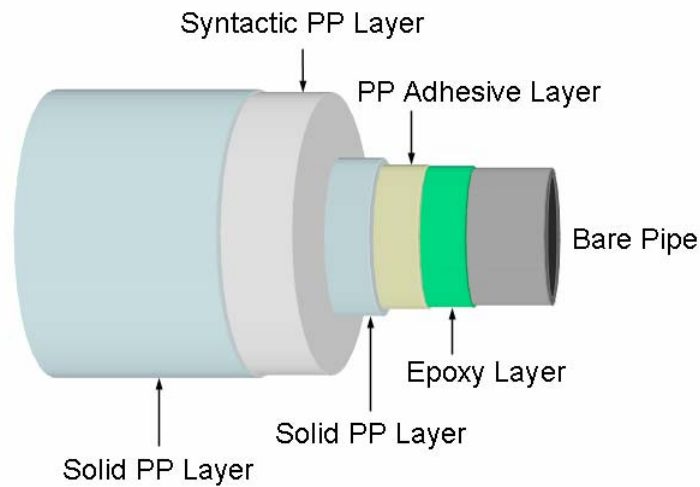


Figure 2: Syntactic PP Coating Structure
[Source: SocoRIL, Argentina]

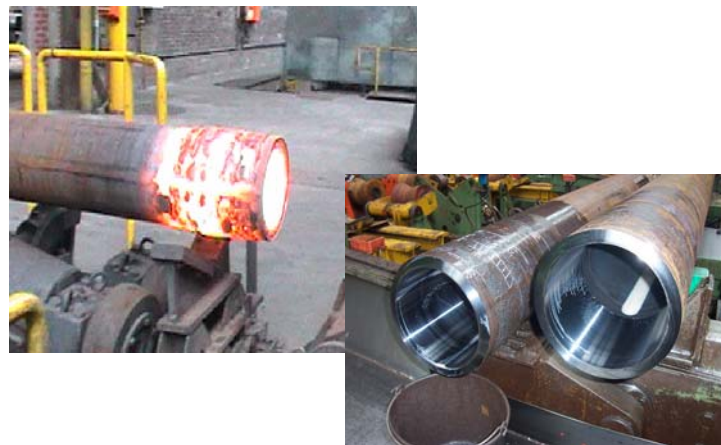


Figure 3: Upset End Solution
[Source: V&M Deutschland, Germany]